Historic, Archive Document

Do not assume content reflects current
scientific knowledge, policies, or practices.

BLISTER RUST INFECTION—RATE OF INCREASE AND LOCAL DISTRIBUTION

The following notes are for the purpose of describing certain short-cut methods of using the type of infection analysis employed in a paper by the undersigned entitled "Progressive Intensification of Uncontrolled Plant Disease Outbreaks," presented at a meeting of the American Association of Economic Entomologists at St. Louis, December 30, 1935, and being published in volume 29 of the Journal of Economic Entomology.

Rate of Increase of Infection.

In figures 1 to 4 and 6 of that paper, it is shown that local blister rust outbreaks in the course of their development follow a typical course which, when plotted, shows an S-shaped curve known as a "logistic curve." By means of a special ruling on cross-section paper, it is possible to arrange the horizontal lines in such a way that these S-shaped curves, when plotted, assume a straight-line form. Such a sheet is attached marked "Chart A." On it are drawn the same curves as are shown in figure 1 of the manuscript. It will be noted that these are now straight lines.

In order that a concrete mental picture can be obtained of the coefficient "m", that is, the rate of increase, it may be stated that the number of years which it takes for an infection to build up at a given locality or under given conditions from 1 per cent to 99 per cent, is $-4 \div m$. By plotting the course of accumulative infection on this special form of paper accordingly, and extending the line if necessary, the rate of increase can be obtained by noting the number of years from the point where the line crosses 1 per cent to the point where it crosses 99 per cent, and dividing -4 by that number of years.

Copies of this special ruling will be supplied those in the blister rust work who are especially interested in such infection analysis. In using the paper it is merely necessary to locate any known percentage of infection with the year in which such percentage occurs. The intervening and past and future courses of the disease, if constantly following a typical development, can be determined by connecting the points so recorded. Other things being equal, the more susceptible Ribes there are in the vicinity, the steeper this line will appear.

This paper can be used for any plots on which the percentage of infection is known for two or more years, whether such years are in succession or are separated by intervening periods. It cannot be used where the infection percentage of a plot is recorded for only one year, except that a rough idea of the direction of the line can be obtained in case the year of introduction of the disease in the locality is also known. In that case, some arbitrary fraction of 1 per cent can be assumed for the infection percentage of the year of introduction based on whatever partial data are available.

If the recorded infection percentages are based on the internode records, as in the East, the line will be in approximately its true position with respect to the years shown at the foot of the chart. In case the infection percentages are based on counts of apparently infected trees on successive dates, the points will be shown on the chart some 2 or 3 yearly divisions to the right of their true position, owing to the incubation period of infection.

Changes in the Rate of Increase.

Weather conditions cause some fluctuation in the rate of increase of infection, but the effect of these is merely to make the line somewhat zigzag without changing its general straight-line form on the chart. The effect of a consistently changing factor, such as an increasing or a decreasing Ribes population, however, causes the line to leave the straight-line form and to bend. It is probably only rarely that the Ribes population remains constant over a period of years in any locality.

The bend is to the right in the case of a decreasing Ribes population and to the left (upward) in the case of an increasing Ribes population. The abruptness of the bend will indicate the rapidity of the change. If the line after sharply bending for several years takes a constant direction for 3 or 4 years, we may perhaps assume that the change in Ribes population has been approximately completed and that the number of Ribes has reached a static condition, in which case the future course of the disease can be anticipated by continuing the curve as a straight line in its new direction.

A precise equation for lines bending in this manner can be determined by the methods described in the published paper, but the computations are laborious, and it is believed that any value there may be in this form of analysis can be obtained by plotting the results on this special cross-section paper without any form of computation.

Geographical Distribution of Source of Spores.

The third conclusion of the paper is "that the effect of the distribution of Ribes in a given environment can be measured by finding out how many more cankers are present upon the trees in the stand in view of the percentage of infected trees than would be there if the Ribes were scattered uniformly among the trees." This conclusion is based on the fact that under the laws of probability, if there is a perfectly uniform distribution of spores over a stand, a given infection percentage will always be associated with the same number of cankers. For example, if 35 per cent of the trees were infected, 43 cankers would always be found in each 100 trees in the stand. If 50 per cent of the trees were infected, 69 cankers would be found for every 100 trees in the stand. The method of determining this theoretical number of cankers is outlined in the paper.

In the case of the blister rust, it is found that there are practically always more cankers than would be present if there were a perfectly uniform distribution of sporidia throughout the pine stand. This is due, of course, to the fact that the Ribes are usually irregularly distributed, occurring in patches among the pines, or are confined to concentrations along one side or at some distance.

In the available data it was found that the difference between the number of cankers actually present and the number which would be expected to develop from a uniform distribution of spores was a constant fraction of the square of the number that would be present in the case of such uniform distribution. This expressed algebraically is

$$c = p + dp^2$$

where c is the actual number of cankers present, p is the probable number which would be present in the case of a perfectly uniform distribution of spores, and d is a constant factor for the stand itself, remaining uniform as long as the Ribes distribution for that particular stand remains constant. The more localized the spore distribution, the larger d becomes; that is, if the Ribes are so located that the sporidia are reaching the same individual trees over and over again instead of being evenly scattered throughout the stand, this constant is much larger than where relatively even distribution occurs.

In order to avoid the necessity of calculating these terms, an alignment chart has been prepared and is attached, marked "Chart B." In order to use this alignment chart, note the observed infection percentage in the stand in the column marked "I" and also the figure in parenthesis in the column marked "P" opposite the infection percentage. Subtract this latter figure in column "P" from the actual number of cankers present per hundred trees, and locate the result on the column marked "C - P."

(It is important to note that the term c refers to the number of cankers per 100 total trees and not to the number of cankers per 100 infected trees. This term, c, is obtained by dividing the total number of cankers found on the plot by the total number of pine trees on the plot and multiplying by 100.)

With a ruler or straight-edge, connect this point on the right-hand line with the observed infection per cent on the left-hand line, and the "d" factor will be shown at the point where this line crosses the middle line of the alignment chart.

For example, in a certain area having 1,000 trees a pine infection survey shows 300 of the trees infected and a total of 800 cankers present. The infection percentage (i) is 30, and the number of cankers (c) per 100 total trees is 80. The probable number of cankers (p) /see column "P", opposite 30/ is 36. Subtract 36 from 80 and the result (c - p) is 44. A straight line connecting 30% in column "I" with 44 in column "C - P" intersects the middle line at about .034.

The same result is obtained by the formula $c = p + dp^2$, since

$$80 = 36 + 1296\ d; \quad d = \frac{80 - 36}{1296} = .034.$$

Opposite the middle line of the alignment chart are shown some suggested interpretations of the spore distribution factor (d). In the data seen so far, the spores have been uniformly distributed and the d factor therefore was very small in two classes of cases occurring in the field, namely, (1) where the Ribes were comparatively evenly distributed throughout the stand, and (2) where the Ribes, although located all in one direction from the stand and outside of it, were at a higher elevation with the result that the wind distributed the spores comparatively evenly over the stand. The other extreme, where d is large, occurs in the stream-type conditions of the West where the pines near the stream may become "plastered" with infection but where, if any considerable area is taken such as a plot leading back a quarter mile from a stream, the total infection percentage for the entire plot may be quite small in comparison with the number of cankers occurring on some of the trees. Thus, in the example given above, the distribution factor of .034 is seen to fall in the stream type class of spore distribution.

Purpose of Charts.

The recording of field observations on "Chart A" and the determination of the spore distribution factor from "Chart B" have, of course, no value as an end in themselves, and the purpose of making the analyses on which these charts were based was to find out some quantitative relationship which is apparently occurring between the number, distribution, and species of Ribes, and the rate of increase of infection under diverse climatic conditions.

It is accordingly desired that all pine infection data available to employees of the blister rust control project and others be recorded on copies of "Chart A," and that they be sent to the Washington office with as extensive information about the number, species, and distribution of the Ribes on the plots concerned as is available. In case accurate counts as to bushes and leaf stem are not at hand, a general statement as to the observer's memory of the Ribes situation has some value and will be appreciated.

Similarly it is desired that in as many instances as possible the spore distribution factor be determined from the alignment chart, "Chart B", and that such information as is available about the nature of the Ribes distribution in the localities concerned be recorded.

The information sent to the Washington office should not be confined to cases either where the data seem to substantiate the author's conclusions or where there are apparent exceptions. In fact, instances in which the blister rust has seemed to behave in a manner which cannot be accounted for by the methods described are especially valuable and worthy of study.

Summary.

For each plot or area where the blister rust infection percentage is known for two or more different years, insert the points on a copy of "Chart A" for each year for which the infection percentage is known and connect the recorded points.

The steeper the line, the larger the number of susceptible Ribes within infecting distance of the pine concerned. In case the line is straight in charts of areas where the infection percentage for three or more years is known, the Ribes concentration has presumably not changed.
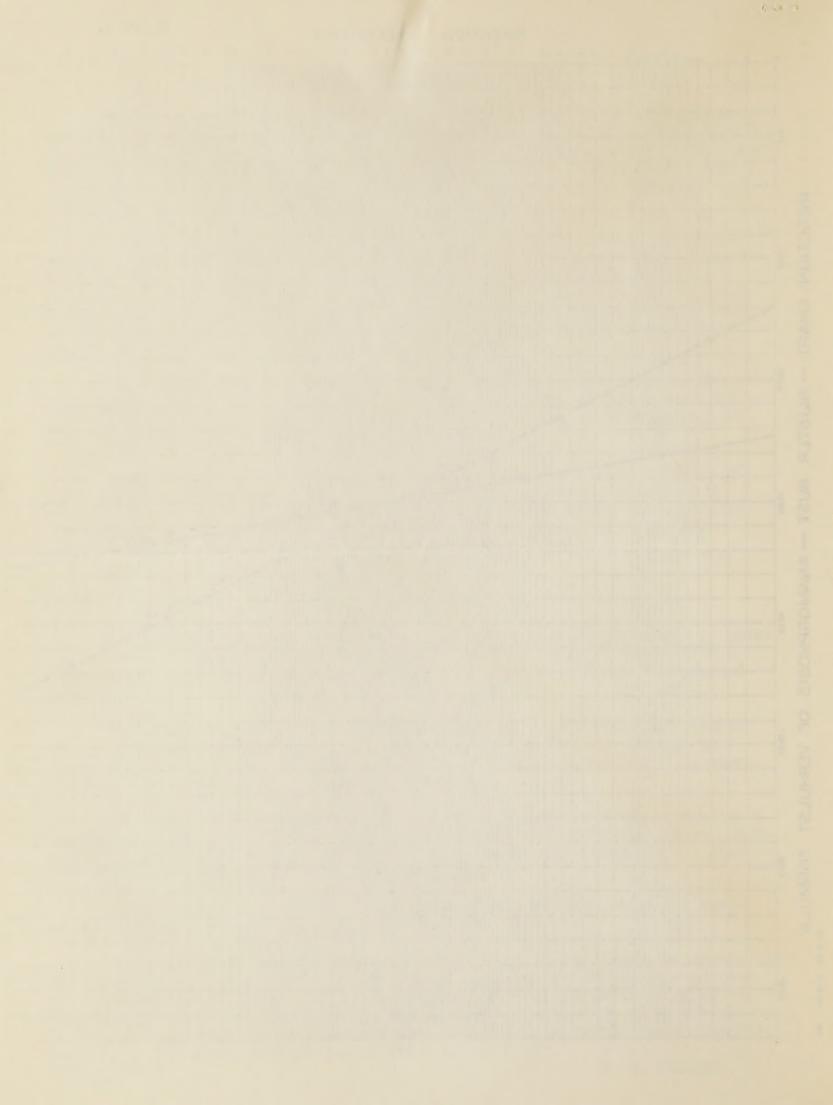
If, in the case of plots or areas where the infection percentage is known for three or more years, the line bends to the right, the susceptible Ribes population was presumably decreasing. If it turns to the left (upward), the susceptible Ribes population was presumably increasing.

Attach notes as to all available information concerning Ribes and their decreasing number or increasing abundance to each "Chart A."

On the spore alignment chart, use a ruler or a straight-edge for connecting the infection percentage (i) on the left-hand line with the excess ($c - p$) over the normal number of cankers (p) on the right-hand line, and note the spore distribution factor on the middle of the three lines. Information is desired as to how the spore distribution factor thus obtained correlates with known regular, spotted, or one-sided distribution of Ribes in the field.

(April, 1936)   S. B. FRACKER

INFECTION PERCENTAGE

INFECTION CHART — BLISTER RUST — ANAMORPHOSIS OF VERHULST FORMULA

WHITE PINE BLISTER RUST

I P   C – P

SPORE DISTRIBUTION
ALIGNMENT CHART

Infection percent

Probable cankers per 100 total trees

Spore distribution factor

Excess of actual over probable cankers

d

.0001

.0002

.0003
.0004
.0005
.0006
.0007
.0008
.001

Spores evenly scattered,
Ribes very uniform or
wind evenly broadcasting
spores.

.002

.003

.004
.005
.006
.007
.008
.01

Spores irregularly
distributed
Ribes patchy.

.02

.03
.04
.05
.06
.07
.08
.09
.1

Spores quite con-
centrated.
Stream type condition.

.2

.3
.4
.5
.6
.7
.8
.9
1.

Infection source
very localized.

$$i = 100\left(1 - e^{-.01P}\right)$$

$$P = 230.26 \log\left(\frac{100}{100 - i}\right)$$

$$c = P + d\,p^2$$

$$d = \frac{c - P}{p^2}$$

Infection percent / Probable cankers per 100 total trees scale (selected values):

99 — (460)
98 — (391)
97 — (351)
96 — (322)
95 — (299)
94 — (281)
92 — (253)
90 — (230)
88 — (212)
86 — (197)
84 — (183)
82 — (171)
80 — (160)
78 — (151)
76 — (143)
74 — (135)
72 — (127)
70 — (120)
68 — (114)
66 — (108)
64 — (102)
62 — (97)
60 — (92)
58 — (87)
56 — (82)
54 — (78)
52 — (73)
50 — (69)
48 — (65)
46 — (62)
44 — (58)
42 — (54)
40 — (51)
38 — (48)
36 — (45)
34 — (42)
32 — (39)
30 — (36)
28 — (33)
26 — (30)
24 — (27)
22 — (25)
20 — (22.3)
19 — (21.1)
18 — (19.8)
17 — (18.5)
16 — (17.4)
15 — (16.3)
14 — (15.1)
13 — (13.9)
12 — (12.8)
11 — (11.7)
10 — (10.5)
9 — (9.4)
8 — (8.3)
7 — (7.3)
6 — (6.2)
5 — (5.1)
4 — (4.1)
3 — (3.0)
2 — (2.0)
1 — 1.0

C – P scale: 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 350, 400, 500, 600, 700, 800, 900, 1000